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MONA LAKE, MUSKEGON COUNTY, MICHIGAN

Pacific Northwest Environmental Research Laboratory

Prepared for:

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivded according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

MONA LAKE

MUSKEGON COUNTY

MICHIGAN

EPA REGION V

WORKING PAPER No. 202

WITH THE COOPERATION OF THE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

AND THE

MICHIGAN NATIONAL GUARD

FEBRUARY, 1975

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F O R E W O R D

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Michigan Department of Natural Resources for professional involvement and to the Michigan National Guard for conducting the tributary sampling phase of the Survey.

A. Gene Gazlay, former Director, and David H. Jenkins, Acting Director, Michigan Department of Natural Resources; and Carlos Fetterolf, Chief Environmental Scientist, and Dennis Tierney, Aquatic Biologist, Bureau of Water Management, Department of Natural Resources, provided invaluable lake documentation and counsel during the course of the Survey. John Vogt, Chief of the Bureau of Environmental Health, Michigan Department of Public Health, and his staff were most helpful in identfying point sources and soliciting municipal participation in the Survey.

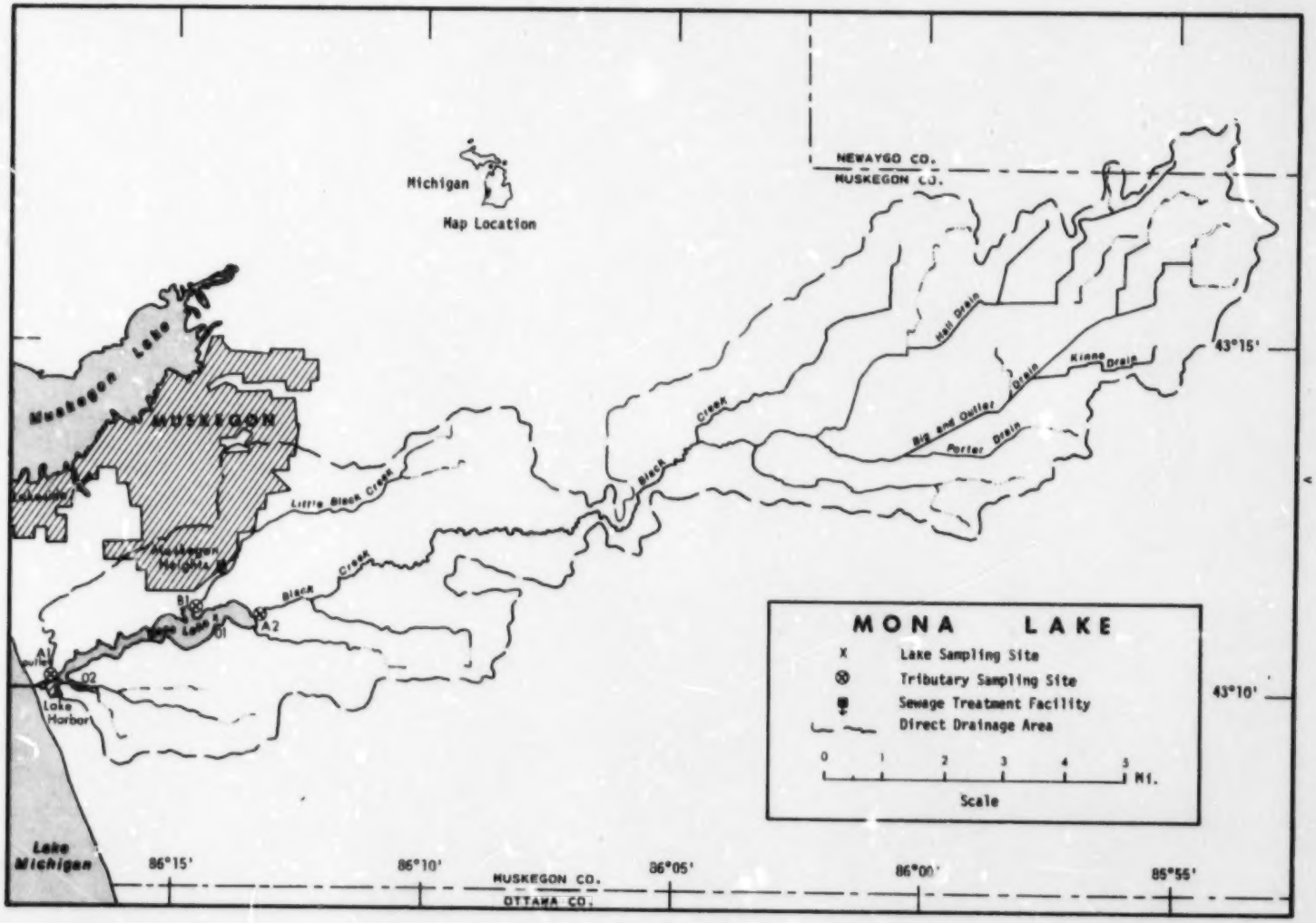
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MICHIGAN

LAKE NAME	COUNTY
Allegan Res.	Allegan
Barton	Kalamazoo
Belleville	Wayne
Betsie	Benzie
Brighton	Livingston
Caro Res.	Tuscola
Charlevoix	Charlevoix
Chemung	Livingston
Constantine Res.	St. Joseph
Crystal	Montcalm
Deer	Marquette
Ford	Washtenaw
Fremont	Newago
Higgins	Roscommon
Holloway Res.	Genesee, Lapeer
Houghton	Roscommon
Jordon	Ionia, Barry
Kent	Oakland
Long	St. Joseph
Macatawa	Ottawa
Manistee	Manistee
Mona	Muskegon
Muskegon	Muskegon
Pentwater	Oceana
Pere Marquette	Mason
Portage	Houghton
Randall	Branch
Rogers Pond	Mecosta
Ross	Gladwin
St. Louis Res.	Gratiot
Sanford	Midland
Strawberry	Livingston
Thompson	Livingston
Thornapple	Barry
Union	Branch
White	Muskegon


Michigan
Map Location
NEWAYGO CO.
MUSKEGON CO.
Muskegon Lake
MUSKEGON
Little Black Creek
Black Creek
Big and Outlet Drain
Porter Drain
Kinne Drain
43°15'
43°10'
Lake Harbor
Lake Michigan
86°15'
86°10'
86°05'
86°00'
85°56'
MUSKEGON CO.
OTTAWA CO.
MONA LAKE
Lake Sampling Site
Tributary Sampling Site
Sewage Treatment Facility
Direct Drainage Area
0 1 2 3 4 5 Mi.
Scale

MONA LAKE

STORET NO. 2691

I. CONCLUSIONS

A. Trophic Condition:

Survey data show that Mona Lake is eutrophic. Of the 35 Michigan lakes sampled in November when essentially all were well-mixed, only one had greater mean total and dissolved phosphorus, and 13 had greater mean inorganic nitrogen; of the 41 Michigan lakes sampled, only six had more mean chlorophyll a, but 17 had less Secchi disc transparency*.

Dissolved oxygen was depleted at 31 feet at station 2 in September and was depressed at about 20 feet at station 1 in June and September.

Ketelle and Uttormark (1971) report that Mona Lake has a long history of algal blooms.

B. Rate-Limiting Nutrient:

The results of the algal assay show that Mona Lake was nitrogen limited in September, 1972. The lake data indicate nitrogen limitation at the other sampling times as well.

C. Nutrient Controllability:

1. Point sources--During the sampling year, Mona Lake received a total phosphorus load at a rate about eight times

* See Appendix A.

the rate proposed by Vollenweider as "dangerous"; i.e., a eutrophic rate (see page 13). Now, Vollenweider's model may not be applicable to water bodies with short hydraulic retention times, and the mean hydraulic retention time of Mona Lake is 76 days.

The sewage effluent of the only known point source impacting Mona Lake (the City of Muskegon Heights) was diverted to a cropland spray-irrigation system in May of 1973 (Bastian, 1974). However, prior to diversion, it is estimated that this source contributed about 84% of the total phosphorus load reaching Mona Lake during the sampling year.

After diversion of the point source phosphorus load, it is calculated that the loading rate was reduced to 0.88 $g/m^2/yr$; and, while this rate is still in excess of the eutrophic rate of 0.68 $g/m^2/yr$, in view of the questionable applicability of Vollenweider's model, it is believed the trophic condition of Mona Lake will improve significantly once a new phosphorus equilibrium becomes established.

2. Non-point sources--During the sampling year, it is estimated that non-point sources, including precipitation, contributed only about 16% of the total phosphorus load to Mona Lake.

The phosphorus export of Black Creek does not appear to have been excessive (see page 13) and is comparable to the

exports of other Michigan streams sampled; e.g., Green Creek and the Muskegon River tributary to nearby Muskegon Lake (Working Paper No. 203).

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 695 acres.
2. Mean depth: 13.4 feet.
3. Maximum depth: 42 feet.
4. Volume: 9,313 acre-feet.
5. Mean hydraulic retention time: 76 days.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
Black Creek	61.6 mi^2	45.5 cfs
Little Black Creek	6.0 mi^2	5.2 cfs
Minor tributaries & immediate drainage -	13.4 mi^2	10.7 cfs
Totals	81.0 mi^2	61.4 cfs

2. Outlet -

Black Creek	82.1 mi^2**	61.4 cfs

C. Precipitation***:

1. Year of sampling: 31.7 inches.
2. Mean annual: 30.0 inches.

† MI Dept. Cons. lake inventory map (1956); mean depth from Fetterolf (1973).
* Drainage areas are accurate within ±5%; mean daily flows for 74% of the sampling sites are accurate within ±25% and the remaining sites up to ±40%; and mean monthly flows, normalized mean monthly flows, and mean annual flows are slightly more accurate than mean daily flows.
** Includes area of lake.
*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

Mona Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two stations on the lake and from a number of depths at each station (see map, page v). During each visit, a single depth-integrated (15 feet or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the second visit, a single five-gallon depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analyses. The maximum depths sampled were 20 feet at station 1 and 31 feet at station 2.

The results obtained are presented in full in Appendix C, and the data for the fall sampling period, when the lake was essentially well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix C.

A. Physical and chemical characteristics:

FALL VALUES

(11/14/72)

Parameter	Minimum	Mean	Median	Maximum
Temperature (Cent.)	6.3	6.5	6.5	6.8
Dissolved oxygen (mg/l)	7.4	10.0	10.3	10.6
Conductivity (μmhos)	440	441	440	450
pH (units)	7.8	8.1	8.3	8.4
Alkalinity (mg/l)	84	105	108	114
Total P (mg/l)	0.238	0.307	0.352	0.369
Dissolved P (mg/l)	0.179	0.241	0.284	0.292
NO_2 + NO_3 (mg/l)	0.300	0.516	0.530	0.580
Ammonia (mg/l)	0.420	0.448	0.430	0.480
SPRING VALUES				
Secchi disc (inches)	36	48	48	60

B. Biological characteristics:

1. Phytoplankton* -

Sampling Date	Dominant Genera	Number per ml
09/19/72	1. Scenedesmus	4,141
	2. Microcystis	778
	3. Cyclotella	307
	4. Stephanodiscus	289
	5. Dinobryon	199
	Other genera	760
	Total	6,474
11/14/72	1. Stephanodiscus	4,792
	2. Flagellates	1,358
	3. Scenedesmus	717
	4. Melosira	491
	5. Chroococcus	415
	Other genera	1,246
	Total	9,019

* The June sample was lost in shipment.

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (µg/l)
06/13/72	01	37.7
	02	50.8
09/19/72	01	19.4
	02	18.9
11/14/72	01	11.8
	02	28.1

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.490	0.990	31.6
0.010 P	0.500	0.990	28.1
0.020 P	0.510	0.990	29.6
0.050 P	0.540	0.990	24.7
0.050 P + 5.0 N	0.540	5.990	137.2
0.050 P + 10.0 N	0.540	10.990	153.2
10.0 N	0.490	10.990	164.9

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Mona Lake was very high at the time the assay sample was collected (09/19/72). Also, the lack of significant change in yields with increased levels of orthophosphorus, until nitrogen was also added, indicates that Mona Lake was nitrogen limited at the time the assay sample was collected. Note

that the addition of only nitrogen resulted in a yield far greater than the control.

Nitrogen limitation is also indicated by the lake data; i.e., the nitrogen to phosphorus ratios were less than 4 to 1 at all sampling times.

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Michigan National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months, when two samples were collected, and the colder months when samples were not taken at B-1 because of low flows. Sampling was begun in October, 1972, and was completed in September, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Michigan District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for the lake outlet and Black Creek were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. However, the nutrient loads calculated for Little Black Creek were less than the estimated Muskegon Heights loads to the creek, so the non-point nutrient loads for Little Black Creek and the unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the nutrient loads, in $lbs/mi^2/yr$, in Black Creek at station A-2 and multiplying by the Little Black Creek and ZZ areas in mi^2.

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* See Working Paper No. 1.

The operation of Muskegon Heights wastewater treatment plant was discontinued in May of 1973, when the Muskegon County land-disposal system became operative. Therefore, the nutrient loads attributed to the Muskegon Heights STP were estimated at 2.5 lbs P and 7.5 lbs N/capita/yr and were adjusted for the eight months of operation that occurred during the sampling year (it is noted that nutrient concentrations in Little Black Creek below the STP had not diminished appreciably through September, 1973).

A. Waste Sources:

1. Known municipal -

Name	Pop.* Served	Treatment	Mean** Flow (mgd)	Receiving Water
Muskegon Heights	17,304	(land disp.)	1.730	Little Black Creek

2. Industrial - Unknown

* 1970 Census.
** Estimated at 100 gal/capita/day.

B. Annual Total Phosphorus Loading - Sampling Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Black Creek	4,000	11.7
Little Black Creek	390	1.1
b. Minor tributaries & immediate drainage (non-point load) -	870	2.5
c. Known municipal STP's -		
Muskegon Heights (8 mos.)	28,840	84.1
d. Septic tanks* -	90	0.3
e. Known industrial - None	-	-
f. Direct precipitation** -	110	0.3
Total	34,300	100.0

2. Outputs -

Lake outlet - Black Creek 25,810

3. Net annual P accumulation - 8,490 pounds

* Estimate based on 150 lakeshore dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Sampling Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
Black Creek	155,640	51.7
Little Black Creek	15,160	5.0
b. Minor tributaries & immediate drainage (non-point load) -	33,860	11.2
c. Known municipal STP's -		
Muskegon Heights (8 mos.)	86,520	28.7
d. Septic tanks* -	3,520	1.2
e. Known industrial - None	-	-
f. Direct precipitation** -	6,700	2.2
Total	301,400	100.0

2. Outputs -

Lake outlet - Black Creek 218,130

3. Net annual N accumulation - 83,270 pounds

* Estimate based on 150 lakeshore dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr
Black Creek	65	2,527

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with very short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	49.4	12.2	433.7	119.8
grams/m^2/yr	5.53	1.37	48.6	13.4

Vollenweider loading rates for phosphorus (g/m^2/yr) based on mean depth and mean hydraulic retention time for Mona Lake:

"Dangerous" (eutrophic rate)	0.68
"Permissible" (oligotrophic rate)	0.34

V. LITERATURE REVIEWED

Bastian, Robert K., 1974. Personal communication (Muskegon County wastewater management systems). EPA Proj. Support Off., Muskegon.

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Vollenweider, Richard A. (in press). Input-output models. Schweiz. Z. Hydrol.

Wasbottom, Thomas, P., 1973. Treatment plant questionnaire (Muskegon Heights STP). MI Dept. Nat. Resources, Lansing.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES SDD-MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 1S-MIN DO
2640	HOLLOWAY RESERVOIR	0.062	0.043	1.461	439.375	10.670	9.200
2641	CARO RESERVOIR	0.117	0.022	3.835	473.000	11.967	9.500
2642	BOARDMAN HYDRO POND	0.006	0.005	0.358	363.500	1.267	6.600
2643	ALLEGAN LAKE	0.123	0.057	1.168	470.222	20.311	12.600
2646	BARTON LAKE	0.121	0.006	1.489	456.167	27.800	14.850
2649	BELLEVILLE LAKE	0.118	0.048	1.420	465.250	28.262	8.200
2650	BETSIE LAKE	0.025	0.008	0.273	481.667	4.567	7.400
2653	BRIGHTON LAKE	0.109	0.073	1.015	456.000	44.233	7.500
2657	LAKE CHARLEVOIX	0.007	0.006	0.230	351.250	3.008	9.240
2658	LAKE CHEMUNG	0.044	0.014	0.132	484.333	13.483	14.000
2661	CONSTANTINE RESERVOIR	0.027	0.008	0.910	456.167	39.317	7.500
2669	FORD LAKE	0.105	0.058	1.536	456.167	14.733	14.000
2671	FREMONT LAKE	0.372	0.342	1.486	441.667	28.500	14.000
2680	JORDAN LAKE	0.180	0.144	1.998	427.667	20.517	14.500
2683	KENT LAKE	0.048	0.015	0.417	485.000	33.944	13.000
2688	LAKE MACATAWA	0.197	0.120	2.358	477.600	25.600	12.200
2689	MANISTEE LAKE	0.018	0.010	0.304	451.333	6.317	11.360
2690	MUSKEGON LAKE	0.087	0.043	0.469	430.444	9.511	14.000
2695	PENTWATER LAKE	0.027	0.017	0.496	430.667	14.083	14.000
2701	RANDALL LAKE	0.246	0.183	0.818	457.333	27.217	8.020
2702	ROGERS POND	0.026	0.015	0.183	439.500	8.133	9.600
2703	RUSS RESERVOIR	0.034	0.021	0.460	465.333	10.383	8.200
2704	SANFORD LAKE	0.016	0.008	0.307	458.750	13.791	8.300
2713	THORNAPPLE LAKE	0.042	0.032	1.737	442.833	14.650	10.000
2715	UNION LAKE	0.083	0.064	1.252	455.500	15.667	8.200
2718	WHITE LAKE	0.027	0.019	0.367	417.778	9.211	13.400
2721	HONA LAKE	0.307	0.241	0.963	451.667	27.783	14.100
2722	LONG LAKE	0.163	0.148	0.749	418.488	10.067	13.600

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES 500- MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 1S- MIN DO
2693	ST LOUIS RESERVOIR	0.134	0.093	1.227	462.667	5.583	8.420
2694	CRYSTAL LAKE	0.009	0.006	0.144	380.000	2.986	13.000
2695	HIGGINS LAKE	0.007	0.005	0.058	268.500	1.043	9.400
2696	HOUGHTON LAKE	0.018	0.008	0.136	420.833	9.217	8.200
2697	THOMPSON LAKE	0.043	0.029	0.436	407.889	11.967	14.800
2698	PERE MARQUETTE LAKE	0.032	0.024	0.346	448.667	11.833	8.600
2699	STRAWBERRY LAKE	0.069	0.050	0.567	419.800	11.117	13.600

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500-MEAN SEC	ALL VALUES: MEAN CHLOHA	ALL VALUES: 15-MIN OD	INDEX NO
2640	HALLOWAY RESERVOIR	46 (16)	43 (15)	17 (6)	57 (20)	60 (21)	63 (22)	286
2641	CARO RESERVOIR	29 (10)	54 (19)	0 (0)	3 (1)	49 (17)	54 (19)	189
2642	BOARDMAN HYDRO POND	97 (34)	97 (34)	69 (24)	91 (32)	94 (33)	97 (34)	545
2603	ALLEGAN LAKE	20 (7)	31 (11)	31 (11)	6 (2)	29 (10)	40 (14)	157
2606	BANTON LAKE	23 (8)	20 (7)	14 (5)	29 (9)	14 (5)	3 (1)	103
2609	BELLEVILLE LAKE	26 (9)	37 (13)	20 (7)	11 (4)	11 (4)	79 (26)	184
2610	BETSIE LAKE	77 (27)	77 (27)	80 (28)	17 (6)	86 (30)	94 (33)	431
2613	BRIGHTON LAKE	31 (11)	23 (8)	34 (12)	34 (12)	0 (0)	90 (31)	212
2617	LAKE CHARLEVOIX	91 (32)	91 (32)	83 (29)	94 (33)	89 (31)	60 (21)	508
2618	LAKE CHEMUNG	49 (17)	71 (25)	94 (33)	86 (30)	46 (16)	11 (2)	357
2621	CONSTANTINE RESERVOIR	71 (25)	83 (29)	40 (14)	29 (9)	3 (1)	90 (31)	316
2629	FORD LAKE	34 (12)	29 (10)	11 (4)	29 (9)	37 (13)	23 (8)	163
2631	FREMONT LAKE	0 (0)	0 (0)	23 (8)	54 (19)	9 (3)	11 (2)	97
2640	JORDAN LAKE	11 (4)	11 (4)	6 (2)	69 (24)	26 (9)	0 (0)	123
2643	KENT LAKE	57 (20)	69 (24)	63 (22)	40 (14)	6 (2)	36 (12)	271
2648	LAKE MACATAWA	9 (3)	14 (5)	3 (1)	0 (0)	23 (8)	43 (15)	92
2649	MACKINAW LAKE	80 (28)	74 (26)	77 (27)	46 (16)	80 (28)	46 (16)	403
2659	MUSKEGON LAKE	37 (13)	40 (14)	54 (19)	60 (21)	69 (24)	11 (2)	271
2665	PENTWATER LAKE	69 (24)	63 (22)	51 (18)	66 (23)	31 (11)	11 (2)	291
2671	RANDALL LAKE	6 (2)	6 (2)	43 (15)	23 (8)	20 (7)	86 (30)	184
2672	ROGERS POND	74 (26)	66 (23)	86 (30)	63 (22)	77 (27)	51 (18)	417
2673	RUSS RESERVOIR	60 (21)	57 (20)	57 (20)	9 (3)	63 (22)	79 (28)	325
2674	SANFORD LAKE	86 (30)	80 (28)	74 (26)	20 (7)	43 (15)	71 (25)	374
2683	THORNAPPLE LAKE	54 (19)	46 (16)	9 (3)	51 (18)	40 (14)	49 (17)	249
2685	UNION LAKE	40 (14)	26 (9)	26 (9)	37 (13)	34 (12)	79 (28)	242
2688	WHITE LAKE	66 (23)	60 (21)	66 (23)	80 (28)	74 (26)	31 (11)	377
2691	WONA LAKE	3 (1)	3 (1)	37 (13)	43 (15)	17 (6)	20 (7)	123
2692	LONG LAKE	14 (5)	9 (3)	46 (16)	77 (27)	66 (23)	27 (9)	239

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500- MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15- MIN DO	INDEX NO
2693	ST LOUIS RESERVOIR	17 (6)	17 (6)	29 (10)	14 (5)	83 (29)	69 (24)	229
2694	CRYSTAL LAKE	89 (31)	89 (31)	89 (31)	89 (31)	91 (32)	36 (12)	483
2695	HIGGINS LAKE	94 (33)	94 (33)	97 (34)	97 (34)	97 (34)	57 (20)	536
2696	HOUGHTON LAKE	83 (29)	86 (30)	91 (32)	71 (25)	71 (25)	79 (26)	481
2697	THOMPSON LAKE	51 (18)	49 (17)	60 (21)	83 (29)	51 (18)	11 (2)	305
2698	PERE MARQUETTE LAKE	63 (22)	51 (18)	71 (25)	49 (17)	54 (19)	66 (23)	354
2699	STRAWBERRY LAKE	43 (15)	34 (12)	49 (17)	74 (26)	57 (20)	27 (9)	284

APPENDIX B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2691 MUNA LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 82.10

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	NORMALIZED FLOWS(CFS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2691A1	82.10	56.00	62.00	87.00	117.00	77.00	54.00	40.00	38.00	40.00	46.00	58.00	63.00	61.43
2691A2	61.60	41.00	45.00	64.00	87.00	58.00	41.00	30.00	28.00	30.00	34.00	43.00	46.00	45.54
2691B1	6.00	5.50	6.40	8.30	9.60	5.70	4.20	2.80	2.20	2.60	3.80	5.20	6.20	5.20
2691Z2	14.50	10.00	11.00	15.00	20.00	13.00	9.00	7.00	7.00	7.00	8.00	10.00	11.00	10.65

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 82.10
SUM OF SUB-DRAINAGE AREAS = 82.10
TOTAL FLOW IN = 737.50
TOTAL FLOW OUT = 738.00

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2691A1	10	72	79.00	29	100.00				
	11	72	81.00						
	12	72	64.00	3	59.00				
	1	73	122.00	7	95.00				
	2	73	85.00	4	127.00				
	3	73	157.00	4	165.00				
	4	73	114.00	6	116.00	27	87.00		
	5	73	121.00	15	98.00				
	6	73	62.00	3	89.00	23	43.00		
	7	73	41.00	10	41.00	23	34.00	24	34.00
	8	73	45.00	27	45.00	28	40.00		
	9	73	38.00	28	42.00				
2691A2	10	72	54.00	29	69.00				
	11	72	56.00						
	12	72	44.00	3	40.00				
	1	73	84.00	7	66.00				
	2	73	59.00	4	88.00				
	3	73	111.00	4	116.00				
	4	73	79.00	6	81.00	27	61.00		
	5	73	86.00	15	70.00				
	6	73	42.00	3	60.00	23	29.00		
	7	73	28.00	10	28.00	23	23.00	24	23.00
	8	73	30.00	27	30.00	28	27.00		
	9	73	26.00	28	29.00				

2

LAKE CODE 2691 MUNA LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
269181	10	72	11.00	29	14.00				
	11	72	11.00						
	12	72	9.40	3	9.00				
	1	73	16.00	7	12.00				
	2	73	11.00	4	16.00				
	3	73	19.00	4	20.00				
	4	73	15.00	6	15.00	27	11.00		
	5	73	15.00	15	12.00				
	6	73	9.70	3	14.00	23	7.00		
	7	73	6.20	10	6.00	23	5.00	24	5.00
	8	73	6.80	27	7.00	28	6.00		
	9	73	5.10	28	6.00				
269122	10	72	14.00						
	11	72	14.00						
	12	72	11.00						
	1	73	22.00						
	2	73	15.00						
	3	73	27.00						
	4	73	20.00						
	5	73	29.00						
	6	73	10.00						
	7	73	7.00						
	8	73	8.00						
	9	73	7.00						

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APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/02/04

269101
43 11 00.0 086 14 00.0
MONA LAKE
26 MICHIGAN

11EPALES 2111202
5 0018 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/13	12 30	0000	19.7	9.0	38	540	9.30	114	0.310	0.260	0.438	0.387
	12 30	0018	17.7	4.2		550	8.95	120	0.250	0.980	0.620	0.540
72/09/19	12 25	0000			60	415	9.00	112	0.260	0.200	0.341	0.302
	12 25	0004	20.1	9.0		425	9.00	112	0.260	0.200	0.349	0.308
	12 25	0015	19.8	6.8		430	8.80	113	0.270	0.400	0.416	0.359
	12 25	0020	19.3	4.7		440	8.18	118	0.150	1.240	0.570	0.523
72/11/14	12 45	0000			48	440	7.80	105	0.580	0.480	0.242	0.187
	12 45	0004	6.3	10.3		440	7.80	103	0.570	0.480	0.240	0.186
	12 45	0012	6.3	10.2		440	7.80	103	0.570	0.480	0.238	0.181
	12 45	0018	6.3	10.2		440	7.80	84	0.300	0.470	0.244	0.179

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DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/13	12 30	0000	37.7J
72/09/19	12 25	0000	19.4J
72/11/14	12 45	0000	11.8J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 75/02/04

269102
43 10 00.0 086 17 00.0
MUNA LAKE
26 MICHIGAN

11EPALES 2111202
5 0014 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/13	01	00 0000	20.0	8.6	36	430	9.30	115	0.180	0.190	0.378	0.335
	01	00 0010	18.4	7.6		440	9.40	116	0.190	0.260	0.369	0.347
72/09/19	12	50 0000			60	422	8.90	116	0.230	0.220	0.426	0.383
	12	50 0004	20.1	9.1		420	8.95	114	0.220	0.170	0.422	0.386
	12	50 0015	19.9	6.9		428	8.85	114	0.210	0.310	0.442	0.394
	12	50 0022	19.1	0.9		440	7.87	118	0.140	0.760	0.459	0.368
	12	50 0031	17.3	0.0		460	7.70	130	0.050	4.360	1.420	1.020
72/11/14	13	00 0000			48	450	8.30	114	0.540	0.420	0.362	0.292
	13	00 0004	6.7	10.6		440	8.40	111	0.530	0.420	0.361	0.284
	13	00 0015	6.7	10.4		440	8.40	112	0.520	0.420	0.369	0.287
	13	00 0022	6.8	10.6		440	8.40	109	0.520	0.430	0.352	0.286
	13	00 0030	6.5	7.4		440	8.30	108	0.510	0.430	0.359	0.284

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/13	01	00 0000	50.8J
72/09/19	12	50 0000	18.9J
72/11/14	13	00 0000	28.1J

J VALUE KNOWN TO BE [illegible] ERROR

APPENDIX D

TRIBUTARY DATA

STORET RETRIEVAL DATE 75/02/04

2691A1 LS2691A1
43 10 00.0 086 17 30.0
BLACK CREEK
26 15 LAKE HARBOR
O/MUNA LAKE
LAKE HARBOR RD BRDG AT LAKEHARBOR
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	09 45		0.530	1.500	0.240	0.294	0.399
72/12/03	09 25		0.820	1.470	0.460	0.240	0.294
73/01/07	10 25		1.060	1.000	0.240	0.069	0.105
73/02/04	09 40		1.120	0.780	0.231	0.052	0.085
73/03/04	10 20		1.360	0.960	0.210	0.035	0.080
73/04/06	16 20		0.970	1.260	0.029	0.058	0.155
73/04/27	13 35		0.660	2.100	0.037	0.042	0.135
73/05/15	11 00		0.580	1.100	0.120	0.115	0.175
73/06/03	07 15		0.190	0.940	0.012	0.054	0.140
73/06/23	14 00		0.096	1.100	0.027	0.092	0.175
73/07/10	16 20		0.105	1.200	0.026	0.115	0.230
73/07/24	08 00		0.010K	1.600	0.023	0.147	0.240
73/08/28	07 50		0.026	1.170	0.250	0.273	0.370
73/09/28	13 05		0.094	1.150	0.330	0.252	0.350

K VALUE KNOWN TO BE
LESS THAN INDICATED

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STORET RETRIEVAL DATE 75/02/04

2691A2 LS2691A2
43 11 00.0 086 13 30.0
BLACK CREEK
26 15 MUSKEGON
1/MUNA LAKE
US BR 31 BRDG E LAKE NE MUSKEGON AIRPORT
11EPALES 211204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	09 25		0.740	3.200	0.231	0.005K	0.038
72/12/03	09 10		0.707	1.250	0.320	0.020	0.042
73/01/07	09 50		0.950	0.940	0.170	0.018	0.037
73/02/04	09 10		0.800	0.840	0.270	0.020	0.040
73/03/04	09 45		0.710	1.000	0.357	0.029	0.057
73/04/06	15 35		0.740	0.885	0.200	0.017	0.035
73/04/27	12 50		0.710	0.920	0.138	0.017	0.035
73/05/15	10 35		0.740	0.850	0.170	0.021	0.040
73/06/03	14 00		0.696	0.950	0.168	0.026	0.075
73/06/23	14 15		0.800	0.860	0.210	0.021	0.045
73/07/10	16 05		0.800	0.560	0.087	0.017	0.040
73/07/23	17 25		0.890	0.640	0.110	0.018	0.030
73/08/27	16 20		1.000	1.200	0.135	0.016	0.040
73/09/26	12 20		0.980	0.935	0.415	0.024	0.065

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/03/04

269181 LS269181
43 11 00.0 086 14 30.0
LITTLE BLACK CREEK
20 15 MUSKEGON
1/MONA LAKE
CITY BRDG S MUSKEGON HEIGHTS
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/02/04	09 05		2.800	4.400	2.900	0.820	1.450
73/03/04	09 35		2.800	3.400	2.500	0.620	1.050
73/04/06	16 00		1.460	0.840	0.060	0.023	0.040
73/04/27	13 00		1.800	0.690	0.042	0.018	0.030
73/05/15	10 20		3.600	4.900	3.200	1.020	1.570
73/06/03	13 45		0.780	2.500	0.370	0.210	1.050
73/06/23	14 10		3.400	2.360	0.950	0.169	0.525
73/07/10	15 50		0.200			0.650	2.050
73/07/23	17 20		1.900	2.300	0.378	0.250	0.790
73/08/27	16 15		0.800	0.540	0.490	0.260	0.360
73/09/28	12 10		11.000	1.320	1.020	0.399	0.730

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